Current State of Insert-Type Hearing Protector Fit-Testing: Follow-On Measurements in the Steel Industry and Fit-Testing in a Mobile Environment

Kevin Michael, Michael & Associates, Inc.,
and
David C. Byrne, National Institute for Occupational Safety and Health (NIOSH) Pittsburgh Research Laboratory

In a previous issue of *Spectrum* (October 1999, 16/4), a system of measuring the attenuation provided by insert-type hearing protectors was described. That report described experiences using the FitCheck (Michael & Associates, Inc.) system in a pilot project involving the steel industry during 1998. The FitCheck system utilizes a set of large custom-designed headphones that stand off of the ears and do not affect hearing protector fit. These headphones are used to conduct audiograms on individuals who wear insert-type hearing protectors, both with the hearing protection devices (HPDs) fitted and with the ears open. The attenuation provided at each test frequency is calculated by first subtracting the ears open threshold from the ears occluded threshold. This value is then adjusted by applying a regression equation correction that allows direct comparison to laboratory data. This small correction factor is applied to account for the difference between headphone and sound field audiometric procedures.

The Personal Attenuation Rating (PAR)

The attenuation across frequency bands can be reduced to a single-number measure of HPD performance, similar to the Environmental Protection Agency (EPA) noise reduction rating (NRR). The chart below shows how to calculate the Personal Attenuation Rating (PAR).

Steel Industry Project Results, 1998–2000

All insert-type HPD wearers at a steel mill were fit-tested in 1998, 1999 and 2000 in conjunction with their annual audiograms. The system was demonstrated to be practical to use in this environment without undue burden to the employees or the industry. Using two fit-testing stations, eight workers were tested per hour. Testing was performed at 250, 500, 1000, 2000 and 4000 Hz. Across these three years, the number of workers tested was 392, 351 and 320 from 1998 to 2000, respectively.

The HPD wearers were instructed to fit the HPDs 'as they normally would' prior to the occluded test session, and no additional training or assistance was provided. As expected, the fitting process indicated a wide variety of skill level in fitting technique. Foam and reusable plugs were often inserted without the opposite hand pulling on the outer ear, and the rolling down of foam plugs was often incomplete.

The results indicated wide variability in the attenuation provided by the HPDs. For example, in 1998, 192 of the 392 workers tested were wearing a single-size reusable earplug with an NRR of 27 dB. The mean attenuation provided during the fit-testing measurement session was 13.3 dB with a standard deviation of 10.4 dB. The test results were bimodal, indicating that the attenuation provided to many of the employees was either very high or very low; 34% of the wearers of this device received greater than 20 dB of attenuation and 35% received

Sample PAR Calculation

Third-Octave Band Center Frequency in Hz	250	500	1000	2000	3150	4000
Assumed Exposure in dB SPL	100.0	100.0	100.0	100.0	100.0	100.0
A-Weighting Correction in decibels (dB)	-8.6	-3.2	0.0	+1.2	+1.2	+1.0
Assumed Exposure in decibels, A-scale (dab)	91.4	96.8	100.0	101.2	101.2	101.0
Overall Level = 107.4 dab						
Measured Attenuation in dB (sample)	19.4	22.4	25.1	30.1	32.8	39.3
A-weighted Exposure Minus Attenuation	72.0	74.4	74.9	71.1	68.4	61.7
Overall Level Under Protector = 79.8 dab						

PAR = 107.4 - 79.8 = 27.6 dB

Any of these frequencies can be omitted from the test without changing the method of PAR calculation.

Figure 1: Distribution of PARs, 1998

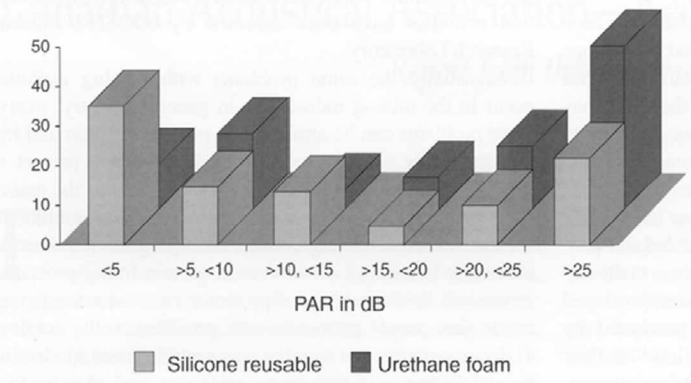


Figure 2: PAR Distribution Across All Plug Types, 1998–2000

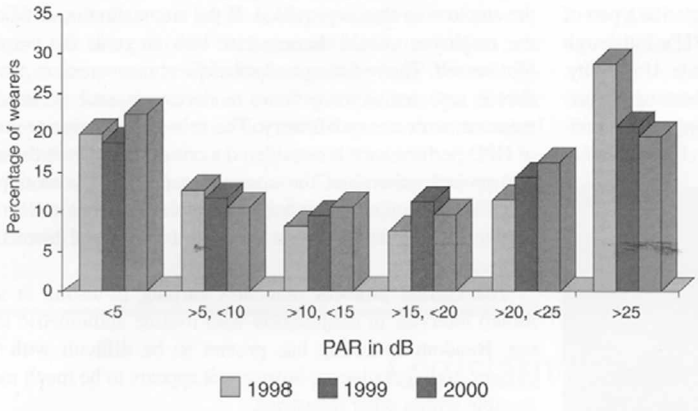
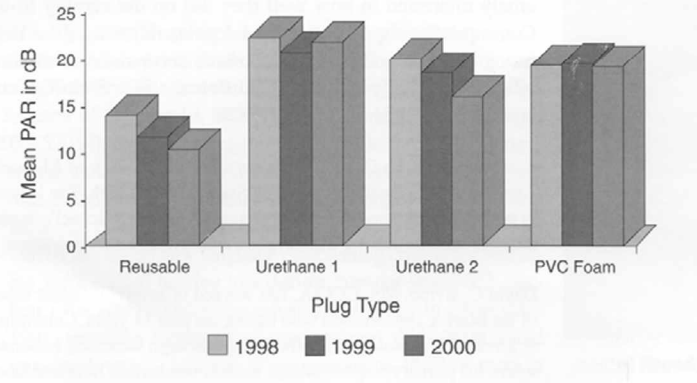


Figure 3: Mean PAR for Specific Plug Models



less than 5 dB of attenuation.

FitCheck test results on foam plugs during the same test period were less bimodal, as figure 1 indicates. Figure 2 shows that the bimodal nature of the overall PAR distribution remained relatively consistent over the three-year period. Management at the steel mill indicated that little change in the hearing conservation program was implemented during the three-year period, so it follows that the fit-testing results would remain constant.

Mean attenuation measurements were consistent for specific models of plugs from 1998 through 2000 as shown in figure 3.

Summary of the Steel Industry Project

Today, all hearing conservationists share the common knowledge that laboratory NRR values represent a *best-fit* condition, and the average attenuation provided to end-users of hearing protectors is often only a fraction of the labeled attenuation values. Further, the attenuation provided to wearers of the reusable-type plugs may be highly variable, as was the case for the particular HPDs used by this study population. The attenuation provided to foam plug wearers was less variable, and the mean attenuation for foam plug wearers was significantly higher than that of the reusable plug. Foam plug mean attenuation values for the three years were 8 dB higher (± 1 dB) than the reusable plug mean attenuation measurements.

Perhaps more important than the particular results, this project demonstrated the need for, and practicality of, individually fit-testing insert-type HPDs. An important finding from this experience was that the fit-testing procedure provides effective training and motivation for the wearer, as well as the hearing conservationist. Workers typically were interested in how well the protector was working, and they were particularly interested in a comparison between the protection they received and the laboratory data.

Multi-Station Fit-Testing in a Mobile Unit

Initial experience with individual earplug fit-testing has been obtained using a stand-alone FitCheck system and testing one subject at a time. Depending on the number of frequencies selected to be included, the test time may be very short or it may last for several minutes. This may not be an issue for hearing conservationists that run their own in-house audiometric testing programs; however, most audiometric service providers cannot afford to spend too much additional time onsite, or keep workers away from their jobs longer during their scheduled shifts.

Since many mobile hearing conservation units use multi-station audiometer systems, a similar group system was developed for earplug fit-testing. The first system was purchased by NIOSH's Pittsburgh Research Laboratory to be used on their mobile Hearing Loss Prevention Unit. This unit is a custom-built fifth-wheel style trailer that contains a single-wall test booth capable of evaluating four persons at a time. A single computer controls both the group testing audiometer as well as the four-station FitCheck system. A photograph of the instrumentation set-up is shown in figure 4.

Evaluation of group fit-testing is being conducted as a part of a cooperative agreement project between NIOSH's Pittsburgh Research Laboratory and the Pennsylvania State University. This project is geared toward developing better hearing conservation programs for the mining industry. Focusing on the mining industry is perhaps fitting, since the development of a field-measurement system for insert-type hearing protectors was initially conducted under a contract for the (former) U.S. Bureau of Mines, whose noise control and hearing loss prevention activities have been assumed by NIOSH's Pittsburgh Research Laboratory.

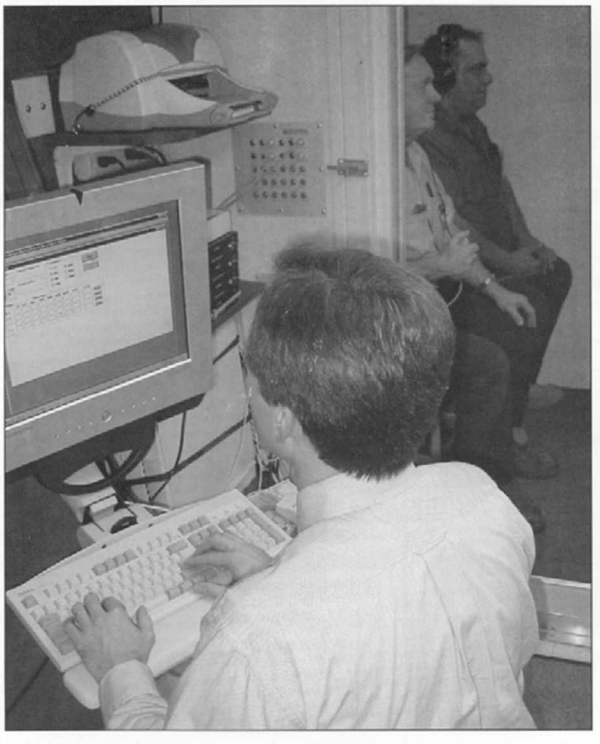


Figure 4: FitCheck instrumentation and test booth in mobile setting.

Essentially the same problems with earplug use/misuse occur in the mining industry as in general industry; many of these problems can be attributed to poor motivation and training on proper wearing techniques. The current project was developed to evaluate and gather information on the assumptions that field measurement systems perform several functions for the industrial hearing conservation program administrator, including 1) training of wearers in correct fitting procedures; 2) random field sampling of protector effectiveness; 3) verification that proper protection was provided to the employee; 4) documentation that training was provided; and 5) identification of failing or deteriorating protectors and changes in ear physiology.

Individual HPD attenuation measurement is particularly valuable as a training tool during the initial selection of earplugs. The hearing conservationist provides any necessary assistance to the first-time earplug wearer and then measures the attenuation that is provided. If the attenuation is sufficient, the employee should demonstrate how to re-fit the earplug him/herself. The re-fitting and subsequent measurement procedure is repeated as many times as necessary until attenuation measurements are satisfactory. The role of field measurement of HPD performance is considered a critical element in the current project; otherwise, the attenuation provided is an unpredictable and unknown variable. Complete records are to be kept to provide evidence that adequate training and protection was achieved.

The current protocol mandates earplug fit-testing at six-month intervals in conjunction with routine audiometric testing. Random fit-testing has proven to be difficult with the current study population; however, it appears to be much more feasible within other industries.

Although multi-station audiometric and earplug fit-testing systems are necessary to accommodate the largest number employees in a minimum amount of time, the results can still be used to personalize the hearing conservation program for each worker. Preliminary results suggest that employees are genuinely interested in how well they did on the earplug fit-test. Consequently, the HPD wearer becomes more involved in the fitting process, and it is this personal acceptance of responsibility that is likely to make the difference in preventing future noise-induced hearing loss.

Kevin Michael, Ph.D, is the director of the laboratory of Michael & Associates, Inc., located at the Penn State Research Park. The laboratory performs evaluation of hearing protectors, and Dr. Michael's research interests include hearing conservation and communication systems.

David C. Byrne, MS, CCC-A, has worked in several different aspects of the hearing conservation field during the past 14 years. Currently, he is a research audiologist at NIOSH's Pittsburgh Research Laboratory where his primary responsibilities include conducting field and laboratory research on the effects of noise exposure in the mining industry.